Preliminary study on land surface characteristics over Huaihe River Basin*

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Abstract The analysis of the flux observation dada from the Huaihe River Basin Experiment (HUBEX) shows that, in semi-humid monsoon regions, latent heat flux is as important as sensible heat flux in most situations. Moreover, it can even dominate the sensible heat flux in cropland and paddy field. This is distinct from that for arid and semi-arid regions where the sensible heat flux is dominant. Under clear sky conditions, the soil temperatures in different vertical layers all exhibit certain diurnal variations, and the magnitude decreases with depth to less than 1℃ at a depth of 60 cm. This depth is considered as the transition layer for the soil moisture variation. On the other hand, the vertical profile of soil water content varies with the soil texture and even weather conditions, and the layer with maximum soil water content can also be found in Jiangji station during June 1998.

Keywords: **Huaihe River Basin, land surface characteristics, soil water content, sensible heat flux, latent heat flux.**

The important role of land surface process in the climate system has been demonstrated by many studies. Especially in the East Asian monsoon region, a better representation of land surface processes in the climate model can lead to prominent improvement of model capability in the simulation of East Asian summer monsoon circulation and its precipitation[1~4]. However, due to the lack of intensive field observational data, especially data on the East Asian monsoon region, there still exist many deficiencies in those state-of-the-art land surface models.[5] Against this back-ground the Huaihe River Basin Experiment (HUBEX), a cooperative project between China and Japan, has been carried out in the East Asian semi-humid subtropics. One of its goals is to have a better understanding of the land surface characteristics and energy and hydrological processes over the Huaihe River Basin, and then to improve the model's capability in the simulation and prediction of the regional and global climate by establishing more sophisticated land surface model suitable for the East Asian monsoon region. In this paper, the characteristics of surface energy balance over the Huaihe River Basin will be analyzed by using the HUBEX field experiment data, and the preliminary results on the distribution and variation of soil temperature and moisture over this region will also be given.

1 Data

The energy flux and soil temperature data used in this paper are the HUBEX field observational data in the Shi-Guan River Basin during spring (May) and summer (August) of 1998 over different land surface (forest, cropland and paddy field), using the flux observation system of Kyoto University (KU-AWS), which can collect four components of radiation, wind profile, air temperature, humidity and soil temperature, and the sensible and latent heat fluxes were calculated by Bowen ratio method[6]. In 1998, there were temperature data about three soil layers of 15, 30 and 45 cm over these observational sites. In 1999, the observational site was moved to Wudaoguo, and the soil temperature at 60 cm was observed, in addition to those layers observed in 1998. The time intervals of the observation were 2 min or 10 min, and then the data were averaged for a period of 30 min in analyses. All these details are shown in Table 1.

Daily soil moisture data over the Shi-Guan River Basin were observed in Meishan (31.4°N, 115.5°E), Nianyushan (31.4°N, 115.2°E) and Jiangji (32.2°N, 115.4°E) respectively in six different vertical layers (15, 30, 45, 60 and 90 cm), and the synchronous daily rainfall distribution was also recorded in these sites[7].

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Table 1. Observational sites and duration for the energy fluxes and soil temperatures during HUBEX

Surface type	Observation site	Duration of observation	Observed parameters
Forest	Tangquanchi 31.7°N, 115.4°E	May 25~29, 1998 Aug. 22~27, 1998	
Paddy field	Yangang 32.0°N, 115.3°E	May 18~24, 1998 Aug.08~15, 1998	Energy fluxes
Cropland	Shuangpu 31.9°N, 115.4°E	May 10~18, 1998 Aug.17~21, 1998	Soil temperature
	Wudaoguo 33.2°N, 117.0°E	Jun 24~Aug. 26, 1999	

2 Near surface energy balance over Huaihe River Basin

Figure 1 shows the surface energy balance for May 1998 over forest, paddy field and cropland. We can find from Fig. 1(a) that in clear-sky and partly cloudy conditions, the daytime latent heat flux was clearly greater than the sensible heat flux over cropland, with the maximum difference about 300 W/m^2 at noon, and the daily averaged Bowen ratio during the observation period was 0.4. Over paddy field (Fig. 1(b)), the daytime latent heat flux was also dominant over the sensible heat flux, except for the daily averaged Bowen ratio in clear-sky condition, which was 0.26 and smaller than that for cropland. However, the averaged Bowen ratio over forest was about 0.95 in clear-sky and partly cloudy conditions, and this might indicate that the latent and sensible heat fluxes were comparable (Fig. 1(c)).

In clear-sky conditions during summer season (August), the daytime latent heat flux was remarkably predominant over the sensible heat flux, with a much smaller daily averaged Bowen ratio of 0.27 than with that in May due to the stronger evapotranspiration in summer (Fig. 1(a)). Over the paddy field, the latent heat flux was even larger (Fig. 2 (b)), and the daily averaged Bowen ratio was taken as 0.13, closer to the typical Bowen ratio over ocean (about 0.1[8]). As for the forest, the latent and sensible heat

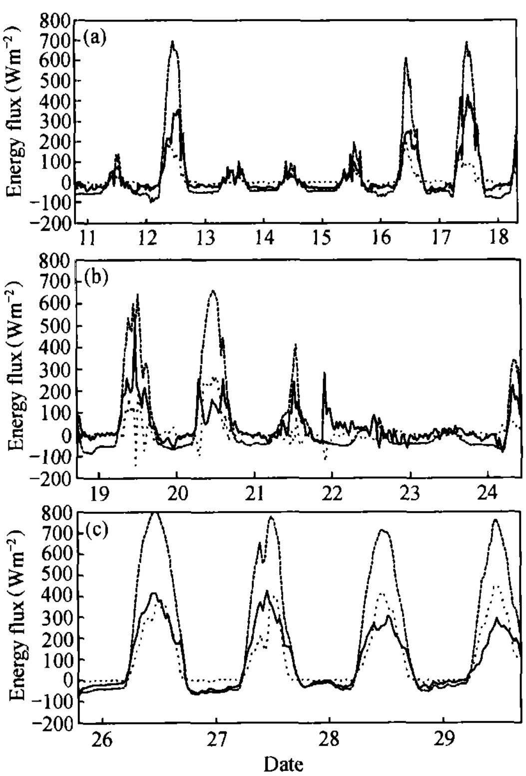

Fig. 1. Surface energy fluxes for May over (a) cropland; (b) paddy field; (c) forest. Short-dashed line indicates the net radiation, solid line the latent heat flux and dotted line the sensible heat flux.

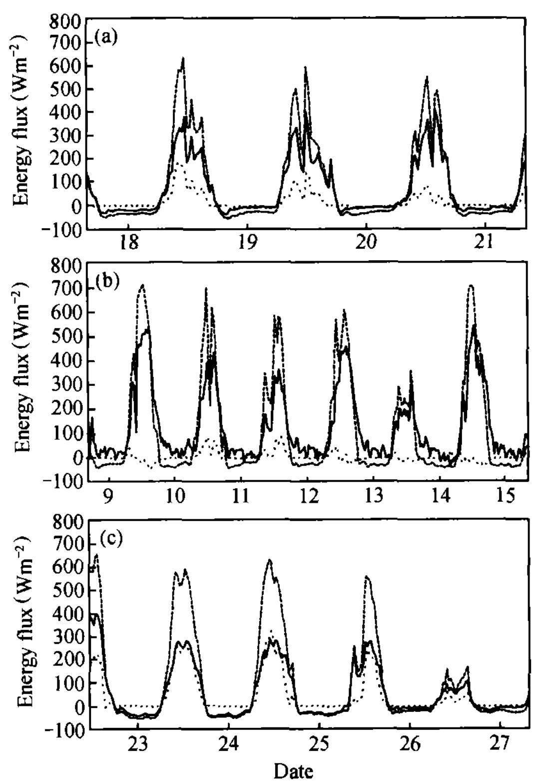

Fig. 2. Surface energy fluxes for August over (a) cropland; (b) paddy field; (c) forest. Short-dashed line indicates the net radiation, solid line the latent heat flux and dotted line the sensible heat flux.

fluxes were comparable with the daily averaged Bowen ratio of about 1.05 (Fig.3(c)).

The above analysis reveals that, for the near surface energy flux balance over the Huaihe River Basin, the sensible heat flux and latent heat flux are of the same importance for spring and summer, and over certain surface types (e.g., cropland and paddy field), the latent heat flux can even dominate the sensible heat flux. This is totally different from the situation in the arid and semi-arid region, where the sensible heat flux is dominant[9].

3 Variation of soil temperature

Fig.3 shows the diurnal variation of soil temperature in May over forest, paddy field and cropland in different vertical layers (15, 30 and 45 cm). We can find that under clear-sky conditions, the diurnal variations of soil temperature in different layers were all remarkable, and the magnitude decreased with the depth. The vertical temperature gradients had opposite sign for daytime and nighttime. Among the three surface types, the diurnal temperature variation was the most prominent over forest; it could reach 10℃ at a depth of 15 cm and then decrease to 3℃ at a depth of 45 cm. As for paddy field, the magnitude of soil temperature variation was the smallest, because the abundant irrigation over paddy field in this season would saturate the soil, and then lead to larger heat content than under the dry conditions, so the diurnal variation of soil temperature became smaller. Generally, for all these types, the average diurnal variation of soil temperature in 45 cm was about 2℃.

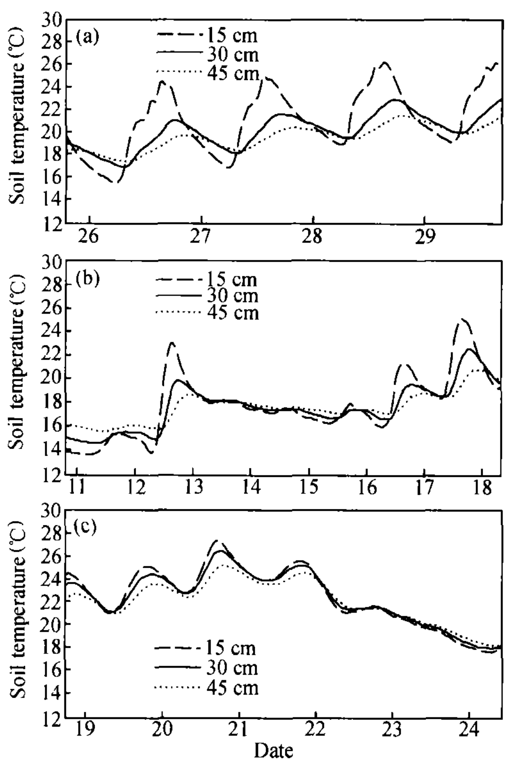

Fig.3. Variation of soil temperature in different vertical layers for May 1998 over (a) forest, (b) cropland and (c) paddy field.

In August, the diurnal temperature variation was also the largest over forest, and smallest for paddy field. However, the magnitude of diurnal variation of soil temperature was generally weaker than the situation for May, e.g. the diurnal temperature variation was about 1.5℃ for forest, and less than 1℃ over paddy field. This may be ascribed to the fact that in August the forest and crop grow luxuriantly over these sites.

Fig.4 shows the diurnal variation of soil temperature over cropland in four different vertical layers (15, 30, 45 and 60 cm respectively) during June to August 1999. Similar to Fig.3, the diurnal temperature variation decreased with depth from 4℃ on the surface to about 2℃ in 45 cm, and it further dropped to less than 1℃ in 60 cm, suggesting that the diurnal variation in layers deeper than 60 cm was not remarkable, and this will be of guiding significance for the division of vertical layers in land surface models.

The analysis of the Huaihe River Basin shows that the diurnal variation of soil temperature is the most significant over forest, and smallest over paddy field. At a depth of 45 cm, the maximum diurnal temperature variation can still remain at about 3℃ over forest in May, although it is relatively small over paddy field. However, to a depth of 60 cm or deeper, the monthly and seasonal variation of temperature is more significant than the diurnal variation.

4 Variation of soil water content

The time evolution of volumetric soil water content in different vertical layers in Jiangji is shown in Fig.5 (a). Generally speaking, due to its strong dependence on the evapotranspiration and precipitation, the soil water content from surface to a depth of 90 cm increases in rainy days, and decreases due to the evapotranspiration, especially on the surface and near surface layers. Temporal evolution of soil water content in Meishan (Fig. 5 (b)) is similar to that of Jiangji,

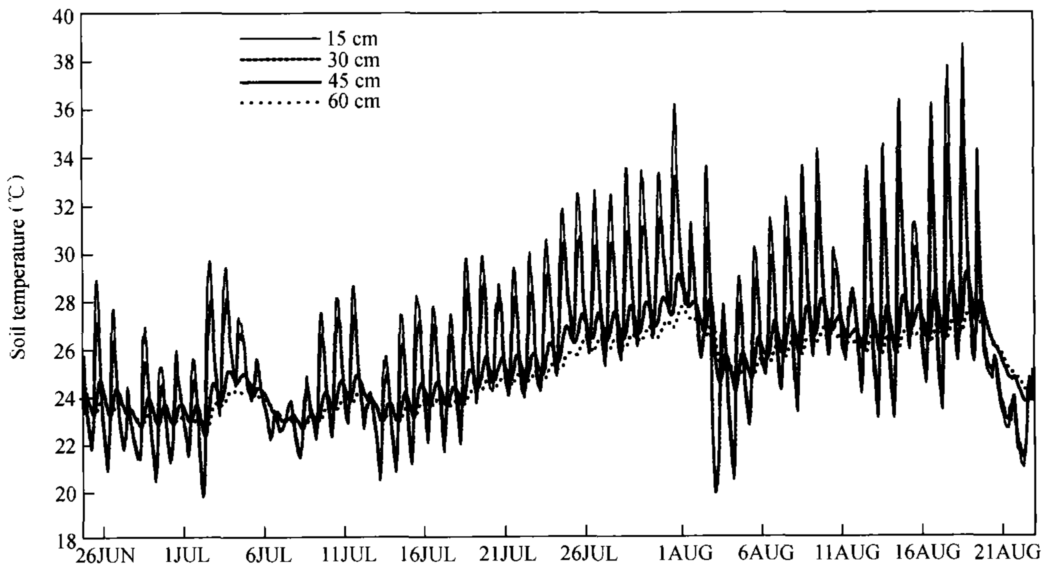

Fig. 4. Variation of soil temperature in different vertical layers over cropland from June to August, 1999.

and this may be ascribed to the loose soil texture at these two sites, which will lead to a relatively high soil hydraulic conductivity.

For Nianyushang station (Fig. 5(c)), we can find that, although the temporal variation of soil water content in shallow layers depends on the precipitation and weather conditions, which is similar to the Jiangji station; for deeper layers (e.g. 90 cm), the time variation of temperature is relatively small, and this may be ascribed to the compact soil texture in Nianyushan, which will lead to the small conductivity of soil moisture. The above results indicate that, for the land surface with compact soil texture, surface soil moisture is apt to evaporate, moisture in deeper soil layers will not evaporate easily. And in rainy days at Nianyushan, rainfall does not penetrate as easily into the deeper soil layers as at Jiangji.

Fig. 6 (a) shows the vertical profile of soil water content in Jiangji in different months and weather conditions. In clear-sky conditions during June, the soil water content from surface to 30 cm increases with depth, then becomes nearly constant from 30 cm to 45 cm, and then increases again with depth and reaches its maximum (about 25%) at a depth of 60 cm, finally it decreases with the depth in the deeper layers. And this may suggest that there exist a maximum soil water content layer at a depth around 60 cm in June. In July, the vertical profile is similar to that in June, except that the layer with maximum soil moisture is located at 30 cm, rather than 60 cm; and beneath 60 cm, the soil water content remains unchanged. In rainy days, although there exists a maximum soil water content layer at a depth of about 30 cm, generally, the whole soil layer keeps nearly the same water content of about 35%, due to the loose soil texture in Jiangji, where the infiltration of rainfall will make the soil nearly saturated.

The vertical profile of soil moisture in Meishan is different from that in Jiangji (Fig. 6(b)). Under consecutive clear-sky conditions in June, the volumetric soil water content in shallow layers (0 ~ 15 cm) increases with depth, and remains nearly constant from 15 to 60 cm, then decreases at depths beneath 60 cm. The reason for this distribution is that precipitation in Meishan before June is scarce, so the whole soil is quite dry during June. Even there is rainfall in June, it is not plentiful enough to penetrate downwards into the deeper layers. In August, the soil water content increases with depth; due to abundant rainfall during the whole summer season, together with the loose soil texture in Meishan, rainwater penetrates the total layer. On the other hand, the surface moisture is weakened due to the strong evaporation under the consecutive clear-sky conditions; but in deeper soil layer, the relative wet condition prevails.

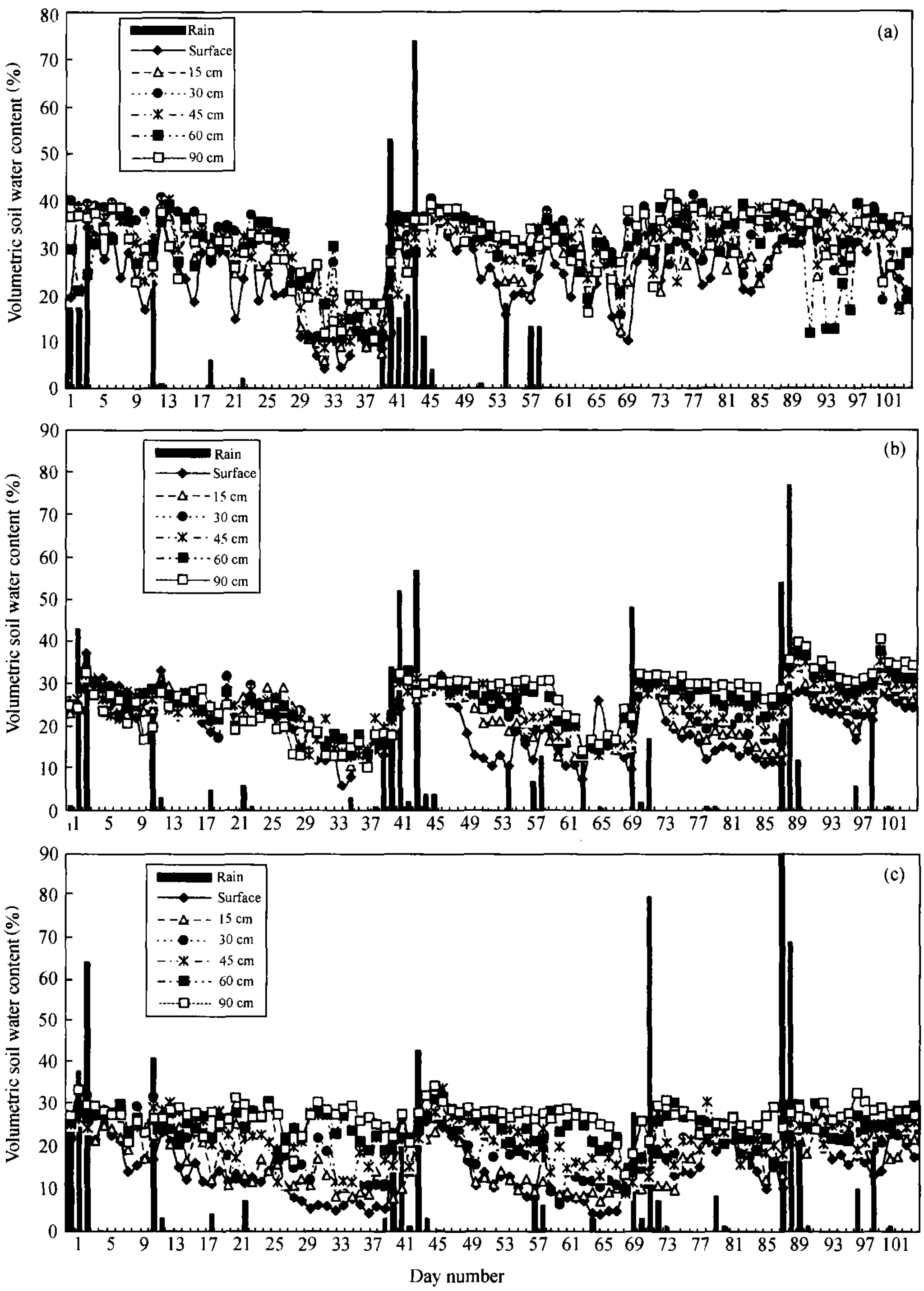

Fig. 5. Variation of volumetric soil water content in different vertical layers from May 21 to August 31, 1998 and daily accumulated rainfall over (a) Jiangji, (b) Meishan and (c) Nianyushan.

In consecutive rainy days, the soil moisture also keeps nearly constant in the vertical direction due to the relatively large soil porosity in Meishan, which is favorable to the downward penetration of rainwater.

At the Nianyushan station, the soil moisture under clear sky conditions increases with depth in both June and July (Fig. 6(c)); however, the layer with maximum soil moisture does not appear, although the vertical gradient of soil moisture decreases slightly under 60 cm. In rainy days, the soil moisture generally increases with depth, with a smaller vertical gradient

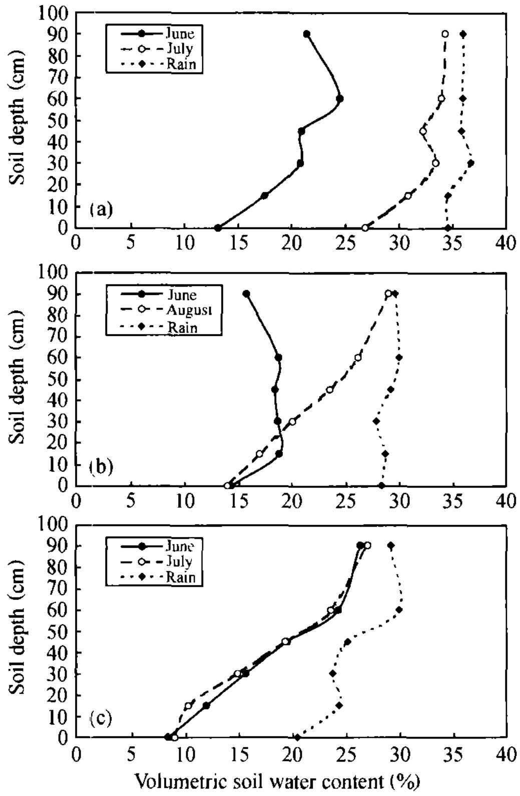

Fig. 6. Vertical profile of daily volumetric soil water content during May 21 ~ August 32, 1998 over (a) Jiangji, (b) Meishan and (c) Nianyushan.

of soil moisture than that under clear-sky conditions, and reaches its maximum at 60 cm, and then decreases with the depth.

The above analysis reveals that, during the HUBEX field experimental period, the frequent precipitation and strong evaporation caused the soil water content in the Huaihe River Basin to fluctuate strongly, especially in the shallow soil layers. However, in deeper soil layers, the variation in water content also depended on the soil texture. For compact soil texture, the soil moisture in shallow layers readily evaporates, but that in the deeper layers (e. g. Nianyushan) does not. As for loose soil texture, the soil moisture in deeper layers can move upwards to fill up the soil moisture deficiency due to the surface evaporation under clear-sky conditions, and in rainy days, rainwater can also penetrate downwards to replenish the soil moisture in the deeper layers, so the soil moisture variations in the upper layers are in the same phase with the deeper soil layers (e.g. Jiangji and Meishan). And these further indicate the importance of correct specification of soil types in land surface models.

On the other hand, the vertical profile of soil water content is also quite complicated, and can vary with time, weather conditions and soil texture. Generally speaking, in the Huaihe River Basin, the layer at 60 cm depth can be regarded as a transition layer for soil moisture; above this layer, the soil moisture is affected significantly by the surface evaporation and precipitation; however, it keeps relatively wet conditions at the layers below, where soil moisture has nearly the same value. Furthermore, as suggested by other studies, there exist a maximum soil water content layer in East China and a permafrost region in the northern Tibetan Plateau[1),[10]]. The layer with maximum soil moisture can also be found in Jiangji during the HUBEX field experiment period. Due to the complexity of the forming mechanism for this maximum layer, it should be further studied in the future with more comprehensive observational dada.

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